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(54) **Methods of using lamellar bodies for therapeutic purposes**

(57) This invention relates to the use of lamellar bodies for therapeutic purposes.

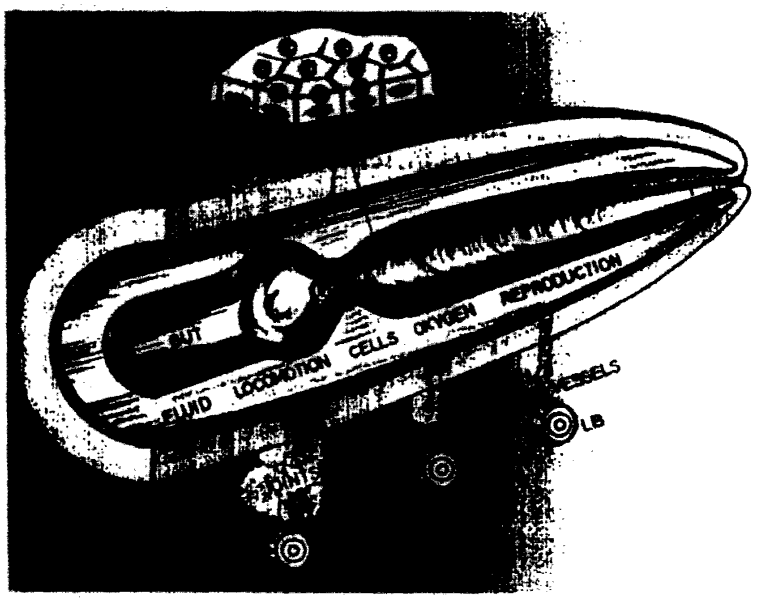

Figure 1

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Description

[0001] This invention relates to phospholipid constructs which act as surrogate lamellar bodies in body cavities, blood vessels, ducts and tissues to modify the deposition and removal of extra and intra-vascular fibrin for therapeutic purposes.

[0002] Many animals possess a coelomic cavity which separates the gut from other structures. Peritoneum, like pleura and pericardium, is a derivative of the coelomic cavity. In the most primitive of animals, consisting only of a cylindrical body wall containing a tubular gut, separation of the two parts by a non-stick derivative of the coelomic cavity is essential if peristalsis is to maintain a flow of nutrition from one end of the gut to the other. Abolition of peristalsis through adhesion of gut to body wall is incompatible with life, thus from the earliest of evolutionary time, provision of a non-stick surface between these vital structures has been imperative. In man, peritoneal adhesions resulting from any cause, whether due to surgery, chronic organismal inflammation or endometriosis, expose the individual to dire consequences.

[0003] In primitive animals, the coelomic cavity is under constant and serious threat from ingress of organisms or noxious molecules from the external environment, either through the gut or body wall. The danger to life is rapid, and unobstructed spread of an invader throughout the entire coelom. Thus there evolved an immediate defensive response whereby the cavity fluid thickens to prevent leakage and entrap invading organisms. This event is achieved by polymerisation of a soluble protein (proto-fibrinogen) into a voluminous network. Medical science and biology in general remain largely ignorant of the primordial site and purpose of the elaborate and now highly evolved mechanism of clotting in the vascular systems of higher vertebrates. This has resulted in a failure to perceive that this system of clotting evolved in tandem with another equally life maintaining system of non-stick properties of the lining surfaces of the coelomic cavity, that is the recently discovered lamellar bodies secretory system. The vast bulk of research into the clotting mechanism is almost entirely vasculocentric and hitherto lack of research into the clotting mechanism in serous cavities has resulted in failure to recognise the crucial role of the lamellar body system in the gelation of fibrin throughout the entire body.

Post Operative Surgical Adhesions

[0004] It is widely recognised in the surgical community that peritoneal adhesions are an extremely common complication of abdominal and pelvic surgery, giving rise to significant morbidity, mortality and unwanted loss of operating time and expense to health services throughout the world. However, until recently, lack of good epidemiological data, combined with an inability to effectively prevent adhesion formation, has limited the impetus to carry out serious investigation of this disorder.

[0005] In the developed world, the most common cause of peritoneal adhesions is abdominal surgery, where the main cause of small bowel obstruction is adhesion formation following previous surgery. Indeed, throughout this century there has been a continual rise in the cases of intestinal obstruction due to adhesions, from 7% in 1930 to 64% in 1969, which reflects the increasing frequency of abdominal surgery in the population at large. It is now recognised that adhesions are responsible for a significant morbidity, loss of work and expense to health services world-wide. With the recent development of minimally invasive surgery, it was hoped that adhesions would be a thing of the past. However, this has not been the case.

[0006] A recent epidemiological study has provided accurate and detailed statistics on the incidents of adhesions, giving evidence of the seriousness of the problem. This study was carried out by the Surgical and Clinical Adhesions Research (SCAR) Group using validated data from the Scottish National Health Service medical record linkage database. It identified patients undergoing abdominal or pelvic surgery in 1986 who had no record of surgery in the preceding five years. Patients were then followed for ten years and subsequent re-admissions were reviewed and outcomes classified by the degree of adhesion. 5.7% of all re-admissions were classified as being caused incontrovertibly by adhesions. A further 28.9% were readmitted with signs and symptoms of subacute obstruction believed to be most probably caused by adhesions. In Scotland in 1994, a total of 4,199 admissions for a population of 5 million were directly related to adhesions. These figures highlight a remarkable scale of adhesion related admissions, when compared to similar figures of other common, essential surgical procedures, such as hip replacement operations (4,394), coronary artery bypass grafts (4,020) or haemorrhoid surgery (4,226) during the same time period and the same population.

[0007] A further effect of adhesions is the difficulty and time taken to dissect them before proceeding with an operation. A study of workload involved for 120 patients undergoing a re-operative laparotomy estimated a mean increase of 24 minutes in the total time of the operation because of intra abdominal adhesions from previous surgery. There is also an intra operative danger of adhesiolysis, as was demonstrated in 274 patients undergoing re-laparotomy where a 21% risk of bowel perforation was identified.

[0008] With respect to mortality, intestinal obstruction is the most severe consequence of adhesions. It has been shown that of patients who require abdominal re-operation, 30% to 41% have adhesion related intestinal obstruction.

[0009] It should be noted that the clinical consequences of adhesions are not simply confined to the gut. Adhesions are the leading cause of secondary infertility in women, and are responsible for substantial abdominal and pelvic pain and discomfort.

[0010] The incidence of post-operative adhesions is becoming increasingly unacceptable to healthcare communities throughout the world. However, recent advances in the molecular biology of serous cavities have at last provided accurate information on the aetiopathogenesis of adhesions which allows evidence based strategies for their prevention during any surgical procedure in any of the derivatives of the coelomic cavity. These new preventative measures involve an understanding of the formation and removal of fibrin in serous cavities. Current knowledge presumes that the only factors are molecular and cellular elements involved in fibrin gelation and fibrinolysis. In the current invention it can be seen that the secretion of lamellar bodies plays a key role in both the physical structure of fibrin deposition and the speed and extent of its removal. The current invention utilises this knowledge to provide therapeutic uses of lamellar body solutions.

The Role of Fibrin in the Acute Inflammatory Response

[0011] Fibrinogen is an acute phase, soluble protein and temporarily increased levels in the blood and tissue fluids are consequences of inflammatory reactions. Contact with pro-coagulant factors causes polymerisation of fibrinogen to form a fibrinous gel.

[0012] At the beginning of the 20th Century, pathologists described and defined the sequence of events in the acute inflammatory response. The reactive changes involved three sequential processes:

1. changes in vascular calibre and blood flow
2. increased vascular permeability and the formation of protein rich inflammatory exudate
3. escape of leucocytes from vessels into extravascular tissue spaces

[0013] An initial event in the tissue spaces is the appearance of fibrin identified by a variety of histochemical techniques. Early histological studies recognised that fibrin represented an attempt to wall-off the infected or damaged area, as well as providing a "scaffolding" of fibres in the turgid oedematous tissue to assist the amoeboid movement of inwardly migrating leucocytes. When looking at acute inflammatory response, an early and orderly disappearance of fibrin heralded a successful outcome to the inflammatory response, as the excess tissue fluid drained away into the lymphatics and the fibrin scaffolding was dismantled.

[0014] Thus, the optimal result of an acute inflammatory response is complete restitution of the normal structure and function of the affected tissue. This process is referred to as resolution or healing by first intention. In the process of resolution, the primary task is the removal of cellular debris and fibrin. If however heavy deposits of fibrin are formed during the early stages of acute inflammation, they may not be removed completely within a few days by the fibrinolytic enzymes of the inflammatory exudate. The consequence of this failure can be profound, as fibrin which is not rapidly removed undergoes a process called organisation. Macrophages migrate into the fibrin, closely followed by ingrowth of new capillaries and fibroblasts to form a tissue known as granulation tissue. As granulation tissue matures, it is eventually replaced by a firm, dense, fibrous tissue more commonly referred to as scar tissue. Where granulation tissue between two opposing tissue surfaces or organs is transformed by this process, the dense fibrous tissue joining the previously separate entities is referred to as an adhesion. This process is also known as healing by second intention and the adhesions may seriously compromise normal function at the site of the original acute inflammatory response.

[0015] In the pre-antibiotic era, the clinical signs and symptoms of fibrinous exudates in response to bacterial infections formed the bulk of everyday medical practice. The sound of a friction rub heard on auscultation of the chest signified a thick fibrinous exudate, the acute inflammatory response of the pleura to underlying pulmonary infection, as in pneumococcal pneumonia. Pericardial friction rubs were also common place, not only in response to diverse infections, but also in uraemia and rheumatic fever. With the complete disappearance of many disease types as medicine advanced, the previously recognised role of fibrinous deposition in most diseased states was not appreciated by the current generation of researchers. An exception to this rule has been molecular biologists working in the field of rheumatoid disorders, where the grossly incapacitating effect of conversion of extravascular fibrin deposits to dense fibrous tissue remains a focus of ongoing research.

[0016] In the last two decades there has been considerable advances in the molecular biology of mesothelium, its reaction to injury and inflammation and its repair and regeneration. A thin mesothelial monolayer resting on a basement membrane covers all of the abdominal organs (visceral) and the wall of the abdominal cavity (parietal). In an adult, its surface measures up to $2m^2$, presenting a large area which acts as a semi-permeable membrane for the exchange of water and small molecular weight solutes. The human peritoneal cavity exists in normal life as a potential space with the opposing surfaces being separated by only 5μ. It therefore contains no more than 50ml of clear, sterile fluid with a low specific gravity and low protein content. Fibrinogen is not present and therefore serous fluid will not clot.

[0017] The local inflammatory response of the peritoneum is similar to other tissues, but the peritoneal lining is unique in that it presents a large exudative and absorptive surface. The lining can separate to accommodate many litres of fluid. At sites of irritation there is an outpouring into the peritoneal cavity of fluid with a high protein content. This exudate contains fibrinogen which polymerises to solid fibrin on contact with local tissue factor released by mesothelium or leucocytes. Plaques of fibrinous exudate forming on the inflamed surface glue ad-

jacent bowel, mesentery and omentum to each other. The process of adhesion is greatly facilitated by the inhibition of peristalsis which allows loops of bowel and omentum to lie undisturbed while the highly adhesive fibrin progressively walls-off the damaged area. Although this process has evolved to localise infection and halt its spread through the entire peritoneal cavity, the same response inevitably occurs when the peritoneum is surgically opened under sterile conditions.

[0018] Thus, as part of the inflammatory response, the mesothelium has a powerful pro-coagulant ability through its local production of tissue factor. This, when released into the peritoneal exudate, initiates a cascade leading to the polymerisation of fibrinogen to solid fibrin. This is balanced by an equally powerful fibrinolytic capability where normal peritoneal tissues contain measurable levels of plasminogen which can be converted to plasmin by the secretion of tissue plasminogen activator. These processes constitute cascade systems finely balanced by activators and inhibitors.

[0019] In this case, the applicant's research has shown that the gelation of fibrin is profoundly affected when it occurs in an environment containing lamellar bodies. Lamellar bodies are a late discovery in modern biology, with their ultrastructural identification and association with the important function of pulmonary secretion of surfactant occurring in 1975. Thus, the presence of lamellar bodies within Type II pneumocytes remained undetected until lung tissue, when fixed in an esoteric mixture of glutaraldehyde and tannic acid, revealed that the vacuoles were not empty, but in fact contained striking geometric configurations of densely osmiophilic, closely packed lamellae. Now intracellular formation of phospholipid lamellae, their vacuole storage as mature lamellar bodies and the exocytotic release from the lumenal surface of Type II pneumocytes as pulmonary surfactant has been firmly established.

[0020] To this day, it is widely believed that the lubricant quality of the sparse fluid present in the peritoneal cavity is solely due to a low concentration of glycosoaminoglycans which diffuses passively from underlying capillaries into the cavity. Due to the poor resolution of the light microscope, the mesothelial cell was for long believed to be a simple passive lining cell. The first electron microscopic study of the human peritoneum revealed the mesothelial cell to be of sophisticated sub-cellular content with a distinctive secretory organisation. Following the observation of the close ultrastructural concordance between mesothelial cells and Type II pneumocytes, studies showed that mesothelium synthesised phosphatidylcholine, the principle constituent of pulmonary surfactant, in amounts equal to those produced by the lung. Subsequently, when specialised fixation techniques developed for the preservation of lamellar bodies were applied to peritoneum, identical structures were found in each and every mesothelial cell. Originally believed to be exclusive to pulmonary alveoli, it was soon established that exocytotic secretion of lamellar bodies in association with surfactant protein A is a wide spread biological system located in the mesothelial lining of all serous cavities and present at a lower density in a variety of other tissues throughout the body.

[0021] The applicant's current research indicates that lamellar bodies subserve surfactant, lubricant, water repellent and transport functions. In serous cavities, its major function would appear to be the highly efficient reduction of friction through self-lubricating ball and roller bearings which constantly form and reform between opposing surfaces.

[0022] It can be seen that it would be advantageous to provide a method of preventing adhesions forming between surfaces during surgical procedures.

[0023] It would also be advantageous to provide a method of dissolving any blood clots and preventing coagulation.

[0024] It is a first object of the present invention to provide a method of preventing or treating adhesions during surgery.

[0025] It is a further object of the present invention to provide a method of dissolving forming, formed and mature(i.e. many days old) blood clots.

[0026] A further object of the present invention is to provide methods that can be easily implemented during surgical procedures.

[0027] According to a first aspect of the present invention there are provided lamellar bodies for use as an active therapeutic substance.

[0028] According to a second aspect of the present invention there is provided a pharmaceutical composition comprising lamellar bodies.

[0029] Preferably the pharmaceutical composition is for the prevention of fibrin clot formation.

[0030] Preferably the pharmaceutical composition is for the modification of fibrin clots.

[0031] Preferably the pharmaceutical composition is for the prevention of adhesions.

[0032] Preferably the pharmaceutical composition is for the treatment of adhesions.

[0033] Preferably the pharmaceutical composition is for the prevention of intravascular clots.

[0034] Preferably the pharmaceutical composition is for the modification of intravascular clots.

[0035] Preferably the lamellar bodies are provided in a solution.

[0036] Preferably the lamellar bodies are provided in combination with any conventional pharmaceutical carrier or excipient.

[0037] Preferably the lamellar bodies are provided in combination with hyaluronan and/or chondroitin sulphate B.

[0038] Optionally the lamellar bodies are synthetic lamellar bodies.

[0039] A further option is that the lamellar bodies are from a natural source.

[0040] A yet further option is that a mixture of natural and synthetic lamellar bodies are used.

[0041] Preferably the pharmaceutical composition is in the form of a spray.

[0042] Preferably the composition is applied at 30 minute intervals.

[0043] Preferably the dosage concentration of the lamellar bodies in the composition is 10 x 10^9 per ml.

[0044] Preferably the lamellar bodies incorporate other active agents.

[0045] Preferably the lamellar bodies incorporate anti-oestrogen compounds.

[0046] Preferably the lamellar bodies may further incorporate chemotherapeutic anti-tumour agents.

[0047] According to a third aspect of the present invention there is provided a use of lamellar bodies for the preparation of an agent for the prevention of fibrin clot formation.

[0048] Alternatively there is provided use of lamellar bodies for the preparation of an agent for the modification of fibrin clots.

[0049] Preferably the use is for the prevention of adhesions.

[0050] Alternatively the use is for the prevention of adhesions.

[0051] Preferably the use is for the prevention of intravascular clots

[0052] Alternatively the use is for the prevention of intravascular clots

[0053] Preferably the lamellar bodies are provided in solution.

[0054] Preferably the lamellar bodies are provided in combination with any conventional pharmaceutical carrier or excipient.

[0055] Preferably the lamellar bodies are provided in combination with hyaluronan and/or chondroitin sulphate B.

[0056] Optionally the lamellar bodies are synthetic lamellar bodies.

[0057] A further option is that the lamellar bodies are from a natural source.

[0058] A yet further option is that a mixture of natural and synthetic lamellar bodies are used.

[0059] Preferably the use of lamellar bodies is during surgical procedures.

[0060] Preferably the lamellar bodies are sprayed onto the area to be treated.

[0061] Preferably the lamellar bodies are applied at 30 minute intervals.

[0062] Preferably the dosage concentration of the lamellar bodies is 10 x 10^9 per ml.

[0063] Preferably the lamellar bodies incorporate other active agents.

[0064] Preferably the lamellar bodies incorporate anti-oestrogen compounds.

[0065] Preferably the lamellar bodies may further incorporate chemotherapeutic anti-tumour agents.

[0066] According to a fourth aspect of the present invention there is provided a process for manufacturing a medicament intended for the prevention of fibrin clot formation, **characterised in that** lamellar bodies are used.

[0067] Alternatively the fourth aspect provides a process for manufacturing a medicament intended for the modification of fibrin clots, **characterised in that** lamellar bodies are used.

[0068] According to a fifth aspect of the present invention there is provided a method of preventing fibrin clot formation by the administration of lamellar bodies.

[0069] According to a sixth aspect of the present invention there is provided a method of modifying fibrin clots by the administration of lamellar bodies.

[0070] According to a seventh aspect of the present invention there is provided a method of preventing surgical adhesions by the administration of lamellar bodies to the site of surgery.

[0071] According to a eighth aspect of the present invention there is provided a method of treating surgical adhesions by the administration of lamellar bodies to the adhesions.

[0072] According to a ninth aspect of the present invention there is provided a method of preventing intravascular clots by the administration of lamellar bodies.

[0073] According to a tenth aspect of the present invention there is provided a method of modifying intravascular clots by the administration of lamellar bodies.

[0074] Preferably the lamellar bodies are provided in solution.

[0075] Preferably the lamellar bodies are provided in combination with any conventional pharmaceutical carrier or excipient.

[0076] Preferably the lamellar bodies are provided in combination with hyaluronan and/or chondroitin sulphate B.

[0077] Optionally the lamellar bodies are synthetic lamellar bodies.

[0078] A further option is that the lamellar bodies are from a natural source.

[0079] A yet further option is that a mixture of natural and synthetic lamellar bodies are used.

[0080] Preferably the administration of the lamellar bodies takes place during surgical procedures.

[0081] Preferably the lamellar body solution is sprayed onto the area to be treated.

[0082] Preferably the lamellar body solution is applied at 30 minute intervals.

[0083] Preferably the dosage concentration of the lamellar body solution is 10 x 10^9 per ml.

[0084] Preferably the lamellar bodies incorporate other active agents.

[0085] Preferably the lamellar bodies incorporate anti-oestrogen compounds.

[0086] Preferably the lamellar bodies may further incorporate chemotherapeutic anti-tumour agents.

[0087] In order to provide a better understanding of the present invention, embodiments and uses of the invention will now be described by way of example only and with reference to the following Figures, in which:

Figure 1 is a diagrammatic representation of the primitive worm showing separation of the gut from the body wall by the coelomic cavity;

Figure 2 is a diagrammatic representation of the appearance of the mesothelium and Type II pneumocytes demonstrating the close similarity of ultrastructural arrangements between cell types;

Figure 3 is a diagrammatic representation based on serial sections of human parietal mesothelium illustrating the form and disposition of lamellar structures;

Figure 4 is a diagrammatic representation based on three dimensional reconstruction of serial electron micrographs of normal human peritoneal mesothelium fixed in freshly prepared tannic acid, glutaraldehyde mixture to preserve a phospholipid bi-layer;

Figure 5 is a simplified diagram based on the three-dimensional reconstruction of Figure 4, showing the mechanics of the lamellar body lubricating system; and

Figure 6 is a diagrammatic representation of the sequential histopathological changes seen in the development of an acute inflammatory response in the peritoneum.

[0088] Please note that throughout this document, the term "lamellar bodies" refers to both naturally occurring and synthetic lamellar bodies.

[0089] In a normal peritoneum, the mesothelial surfaces are separated by a thin film of fluid (4μ to 5μ) containing lamellar bodies. The role of this layer is for the reduction of friction and promotion of movement between opposing surfaces, as can be seen in Figures 4 and 5. In a response to acute inflammation, this lubricating system is directly opposed by the formation of fibrin, whose prime purpose is the promotion of adhesion and reduction of movement at the locus. Therefore, it inevitably follows that these two systems are in a state of biological balance as, following resolution of an acute inflammatory response, the fibrin is totally removed and the lubricating layer returns, along with movement and function.

[0090] In a situation where frequent access to the peritoneal cavity through insertion or removal of catheters, and the four times daily infusion and drainage of 8 to 10 litres of dialysate fluid in hundreds of thousands of patients, the peritoneal cavity acted as a living test tube where its reaction to a wide variety of stimuli was obvious to both patient and medical advisor. It became clear clinically and pathologically that fibrin exudation was a frequent feature of the therapy.

[0091] Relatively simple *in vitro* models have been devised for studying fibrin gelation. Since polymerisation of soluble fibrinogen to polymeric fibrin is the central event in intravascular clot formation, the establishment of a model free from the clutter of other blood elements, such as erythrocytes, leucocytes and platelets is important for studying the process in an environment in which the number of variables is limited. Using such a model, the effect of addition or subtraction of individual reactants can be studied with greater confidence in the reliability of findings.

In vitro Models of Fibrin Gel Networks and Factors Influencing Their Formation

[0092] The fibrinogen molecule is an asymmetric rod-shaped dimer (approximately 10 x 45nm). On activation, the fibrinogen molecules polymerise by end to end and side to side association, thereby forming protofibrils. The protofibrils associate to form fibrin fibres and the latter join into bundles of larger widths. Protofibrils are believed to be twisted in a helical manner, reflecting an indigenous screw symmetry in the fibrinogen molecule itself. Fibrin fibres are also twisted and grow to a limiting size. The limitation in growth is explained as a consequence of stretching of protofibrils near the surface of the fibre. When the amount of energy necessary to stretch a protofibril exceeds energy available for bonding, lateral growth then ceases.

[0093] Hydrated fibrin gels have been studied by a variety of physico-chemical methods, by light and electron microscopy, liquid permeation and turbidity. The gels from normal human fibrinogen were found to be composed of straight rod-like fibre elements, some of which originate from denser nodes. Increasing concentrations of thrombin or fibrinogen form gel networks which become tighter, the fibre strands shorter and the porosity decreases. Gel porosity of the network also decreases in gels formed at increasing ionic strengths. Albumin and dextran, when present in the gel-forming system, are known to produce more porous structures. Thus, albumin is believed to be among the determinants for formation of this type of gel structure in plasma.

Effect of Surrogate Lamellar Bodies on Fibrin Gelation in *In vitro* Models

[0094] Synthetic lamellar bodies were made using a mixture of phospholipids - phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol in 0.9% sodium chloride. The size range of the synthetic lamellar bodies and the ultrastructural configuration of the lamellar bilayers were shown by transmission electron microscopy to be congruent with naturally occurring lamellar bodies. The synthetic lamellar bodies were also tested for sterility.

[0095] Fibrin clots were formed using human fibrinogen and human thrombin. The fibrinogen at 2mg per ml and thrombin at a final concentration of 0.05μg per ml were aloquotted on a 0.5M tris-HCl buffer + 0.1M sodium chloride + 0.018M calcium chloride. To 200μL of fibrin-

ogen solution, 25μL of thrombin was added, mixed and allowed to clot for 60 minutes. The formed clot was then overlain with 200μL of buffer and incubated for one hour at 37°C.

[0096] Fibrin gelation is influenced by the ionic strength of solution. Thus, the dilution effect of adding synthetic lamellar bodies made in 0.9% sodium chloride was compensated by appropriate adjustments in fibrinogen and thrombin concentrations. The effect of changes to the salt balance and clot formation and structure was also independently analysed and characterised. Clots formed with and without synthetic lamellar bodies were initially made in specially adapted cryo-vials to facilitate easy clot removal. Subsequent clots made for different studies were formed in 2ml syringes, 48 microtitre plates and semimicro plastic cuvettes.

The Gross Characteristics of Standard Fibrin Clots and Clots Formed in the Presence of Synthetic Lamellar Bodies

[0097] Fibrin clots formed in the *in vitro* model were white in colour with a variable translucency. Synthetic lamellar body containing clots were also visibly more translucent than standard clots. They did not adhere to plastic and glass surfaces in contrast to standard clots which were strongly adherent to plastic and glass surfaces.

[0098] The difference between clots formed under standard conditions and those formed by adding increasing concentrations of synthetic lamellar body is directly related to the porosity of the clot. In turn, clot density is a function of the degree of separation of the fibrin fibres, which is dependent on the concentration of synthetic lamellar bodies present at the onset of gelation.

[0099] The three dimensional structure of the gel reflecting its density can be accurately measured and expressed in three modes:

1. ultrastructure of fibrin network by transmission and scanning electron microscopy;
2. absorbence of transmitted light at 620Å; and
3. impedance of fluid passage through the gel.

[0100] Time course studies of the dynamic process of gelation were investigated using all three methods of measurement. These showed that addition of even small amounts of synthetic lamellar bodies significantly altered the time course of polymerisation of fibrinogen to fibrin.

Ultrastructural Morphology of Standard Fibrin Clots and Clots Formed with Synthetic Lamellar Bodies

[0101] The morphology of clots formed with different concentrations of synthetic lamellar bodies, when compared to that of standard clots, provided considerable insight into the effect of synthetic lamellar bodies on gelation. Clots examined by transmission and scanning electron microscopy were fixed in 2.5% glutaraldehyde, 2% tannic acid mixture and post-fixed in 1% osmium tetroxide in order to preserve the synthetic lamellar bodies.

[0102] On scanning electron microscopy, standard clots showed a dense network of branching and interlaced solid fibres of fibrin. Additionally, numerous small nodules were regularly distributed throughout the fibres. The three dimensional ultrastructural appearances, relative thickness and separation of the fibres, together with nodules, were closely similar to those encountered in the many peritoneal biopsies of human peritoneum exhibiting freshly deposited fibrin. The *in vitro* clots and the peritoneal biopsies were fixed and processed in identical fashion. Thus, the close ultrastructural concordance between *in vitro* fibrin clot formation and *in vivo* peritoneal extravascular fibrin formation gives considerable credence to and hence confidence in the results of information derived from the *in vitro* model.

[0103] Transmission electron microscopy of standard fibrin clots showed moderately osmiophilic, fine fibrils arranged in bundles separated from each other by regular clear spaces. Again, the ultrastructural appearances were closely similar to those seen *in vivo* in peritoneal biopsies from dialysis patients.

[0104] Scanning electron microscopy of fibrin clots formed with different concentrations of synthetic lamellar bodies showed significantly different three dimensional architecture from that seen in standard fibrin clots. Fibrin fibres were coarser, more irregular and ragged than those seen in standard clots. Spaces within the network were greater due to wider separation of fibres.

[0105] Transmission electron micrographs of fibrin clots formed with synthetic lamellar bodies displayed a radically different ultrastructural appearance to that encountered in standard clots. Whereas in standard clots the geometry was exclusively one of fibrin fibres arranged in a rectilinear network, in clots formed with synthetic lamellar bodies, the fibres showed additional geometric configurations which were curvilinear or circular, reflecting the vesicular nature of the synthetic lamellar bodies. As shown by scanning electron microscopy, the network was looser due to widening of spaces between fibres.

Absorbance of Transmitted Light at 620Å

[0106] The two reactants, fibrinogen and thrombin, are soluble in electrolyte solution to give a clear fluid with only minimal absorbence of light. The dynamic process of polymerisation confers an opacity or turbidity which increases with time up to a limit. This process can be accurately recorded in a spectrophotometer by measuring absorbance of light at 620Å. In standard fibrin clots there is a rapid development of turbidity which reaches a maximum within a relatively short period. Synthetic lamellar bodies possess low turbidity as do natural lamellar bodies. Addition of synthetic lamellar bodies at the same time as the mixing of thrombin and fibrinogen produces

a clot which shows a significantly different pattern of light absorbance to that seen in the process of standard clot formation. The turbidity develops more slowly, and after plateauing at a maximum, lower than that seen in the standard fibrin clot, the turbidity falls back to base levels over a 24 hour period. The observations on turbidity indicate that synthetic lamellar bodies grossly alter the process of clot formation, both chronologically and structurally, reflecting alteration in the rate and manner of polymerisation of fibrinogen to fibrin. This shows that incorporation of synthetic lamellar bodies into a forming clot results in its dissolution after 24 hours to 5 days, dependant on the volume and concentration of synthetic lamellar bodies and the volume of the clot.

Impedance of Fluid Passage Through Standard Fibrin Clots and Clots Formed with Synthetic Lamellar Bodies

[0107] Comparison of the rates of flow of a fluid through gel networks is a measurement of relative pore size in the test of material. A simple experiment carried out using a standard fibrin clot and a fibrin clot containing synthetic lamellar bodies can be formed in a 2ml syringe. A Whatman filter paper was placed over the base of the syringe to cover the aperture. At a fixed pressure, the rate of passage of buffer through the syringe can be measured. This shows that the passage of fluid through a synthetic lamellar body-containing clot is at least 30% faster than in the standard fibrin clot, indicating a significantly greater pore size in clots formed in the presence of synthetic lamellar bodies.

Effect of Addition of a Saline Solution Containing Synthetic Lamellar Bodies to Pre-formed Standard Fibrin Clots

[0108] Using the same concentrations of synthetic lamellar bodies as were incorporated in actively forming fibrin clots, experiments were carried out where synthetic lamellar body solutions were overlain at different time intervals to pre-formed standard fibrin clots. It was found that at room temperature and at 37°C application of synthetic lamellar bodies resulted in dissolution of the clot by 24 hours to 5 days, dependant on the volume and concentration of synthetic lamellar bodies and the volume of the clot. Fibrin clots in an *in vitro* system using only thrombin possessed relatively weak non-covalent lateral bonding between fibres. For a stable fibrin network Factor 13 (fibrin stabilising factor), a transamidase is required to effect lateral bonding through the formation of peptide linkages.

Effect of Addition of a Saline Solution Containing Synthetic Lamellar Bodies on a Pre-formed Human Whole Blood Clot

[0109] Freshly collected venous human blood is collected and allowed to clot in tubes. After one hour, when clot retraction has occurred, the serum is decanted and a saline solution containing synthetic lamellar bodies is added. After 24 hours to 5 days, dependant on the volume and concentration of synthetic lamellar bodies and the volume of the clot, the clot is almost completely dissolved. Clots aged in buffer at 37°C for 24 hours to 5 days also show a similar degree of dissolution following after 24 hours to 5 days exposure to synthetic lamellar body containing solutions.

Mode of Action of Synthetic Lamellar Bodies in Fibrin Formation and Fragmentation

[0110] Lamellar bodies represent a unique agent for influencing the polymerisation of fibrinogen to fibrin during the active process, and also influencing the fragmentation of pre-formed fibrin. Their action in this respect is unique, as they are not proteolytic enzymes. Synthetic lamellar bodies, as surrogate lamellar bodies, are microbodies 0.4 to 3μ in diameter, in contrast to globular protein molecules which are the predominant players in the coagulant and fibrinolytic cascades.

[0111] Investigations carried out by the inventor indicate that part of the mode of action of synthetic lamellar bodies is to sequester Factors involved in coagulation by attachment to the phospholipid bilayers. Since synthetic lamellar bodies are multi-lamellar and highly deformable, they can form and reform when in contact with each other. This property of exposing a constantly changing surface layer confers synthetic lamellar bodies with a massive capacity to adsorb and entrap factors crucial to the coagulant cascade.

[0112] As mentioned previously, the fibrinogen molecule is an asymmetric rod-shaped dimer which, on activation, polymerises by end-to-end and side-to-side association, forming protofibrils. The protofibrils associate to form fibrin fibres and the latter join into bundles of larger widths. The protofibrils are twisted in a helical fashion. The fibrin fibres are also twisted. Helical twisting determines the absolute diameter of the fibrin fibres, in that accretion of fibres stops when the torque of the outer fibres increases to the point that the amount and energy necessary to the stretch the outer protofibrils exceeds the energy available for bonding. The innate twisting of fibrin fibres sets a limit on the lateral aggregation and hence radial growth. Fibrin fibres are known to conform to a three dimensional rectilinear geometry in the fibrin network. Although both protofibrils and fibres are twisted to confer maximum strength, the fibres themselves are not curved but rectilinear. When looking at pure fibrin clots, the size and plasticity of the synthetic lamellar bodies allow them to percolate through and between the fibrin threads in the developing reticulum. The spherical presence within a developing rectilinear fibrin network will impose abnormal structural strain on the fibrils whose self-assembly in polymerisation is dependent on helical twisting. Therefore, fibres forming around curvilinear microbodies will be subjected to an additional mechanical

strain where bending of the fibres will create a higher energy level in the protofibrils on the outer aspect of the convexity and overcome the bonding energy between the protofibrils. This will result in fibres of significantly reduced size through the imposition of a new lower limit on the radial diameter of the fibres. Thus, the presence of synthetic lamellar bodies within a developing clot will introduce a mechanical strain restricting the formation of self-sustaining, self-propagating fibrin networks.

Therapeutic Uses of Natural and Synthetic Lamellasome Solutions

[0113] As synthetic lamellar bodies mimic the action of natural lamellar bodies, both of these can be used as therapeutic agents for a number of uses. Synthetic lamellar body solution, with and without addition of hyaluronan and/or chondroitin sulphate B, provides a method of modifying the deposition and/or removal of fibrin in situ in most tissues, cavities, blood vessels and ducts without requiring anticoagulants or proteolytic fibrinolytic enzymes which have life threatening systemic side effects. Thus, the key role of synthetic or natural lamellar bodies in therapies is the provision of targeted local modification or lysis of fibrin or whole blood clots. This means that synthetic lamellar bodies can be used in therapies where anti-adhesion or anticoagulant properties are required.

[0114] In particular, lamellar bodies can be used in the treatment of two principle groups of disorders:

1. The restoration of normal structures and function in sites subjected to acute inflammatory reaction, through the removal of extravascular fibrin to permit healing by first intention. Lamellar bodies can be used to prevent or modify the formation of granulation tissue, thus preventing scarification and loss of function.
2. Lamellar bodies can also be used to treat intravascular and extravascular whole blood clot formation. Synthetic lamellar bodies will be used to either prevent or modify intravascular clotting in confined segments of the vascular tree. This can be used as a preventative measure in situations involving vascular surgery and intra-vessel manipulations, such a coronary angioplasty, resulting in procoagulant activity and/or micro-emboli in distal arteriolar and capillary beds. Synthetic lamellar bodies can be used to treat intravascular thrombosis by being injected into preformed clots in vessels of all calibres in the arterial tree. Synthetic lamellar bodies in solution may also be used to liquefy haematomas by direct injections. This treatment would be applicable where local swelling is causing acute functional compromise or where more rapid dispersal of haematoma by synthetic lamellar bodies would prevent slow healing by granulation tissue, causing scarification and disfigurement.

[0115] Synthetic lamellar bodies can be used as anti-adhesion agents in all forms of surgery. In particular, lamellar bodies in solution can be used in operative procedures in peritoneal, pleural, pericardial, joint cavities and tendon sheaths. Lamellar bodies may also be used in neurosurgery.

Example of Lamellar Bodies Being Used in Operations in the Peritoneal Cavity

[0116] In open abdominal surgery, the surfaces of visceral and parietal peritoneum, in as wide an area as possible, are lightly sprayed with 2ml of synthetic lamellar bodies before any surgical manipulation is carried out. The synthetic lamellar bodies with their entrapped fluid become emeshed in the dense microvillous surface carpet of the exposed mesothelial cells, before the deleterious effect of air drying commences. A thin layer of synthetic lamellar bodies protects the mesothelium from drying. The synthetic lamellar bodies are therefore in situ in increased density at the beginning of the operation, where the abnormal stimulus of opening the cavity induces fibrinogen exudation and fibrin deposition over the surface of the exposed peritoneal lining. Thus the fine fibrin network which typically develops at the beginning of operative procedures will take place in an environment of increased density of synthetic lamellar bodies. Extravascular fibrin clots formed ab initio will therefore contain synthetic lamellar bodies, resulting in the formation of a fibrin network which is less dense than normal and which will be open to fibrinolytic degradation by synthetic lamellar bodies and the fibrinolytic system.

[0117] The median dose that is sprayed on each occasion when used is 1ml. The ideal concentration of synthetic lamellar bodies is 10×10^9/ml. 100 microlitres of synthetic lamellasome solution sprayed evenly will cover $1m^2$ of peritoneal surface to a depth of 3μ. According to the nature of operative procedure, a further 1ml of synthetic lamellar body solution should be sprayed over the entire operative area every 30 minutes throughout the procedure. A final 2ml of synthetic lamellar body solution should be sprayed evenly around the peritoneum immediately before closing the abdomen. In an abdominal operation lasting 4 hours, the total volume of synthetic lamellar body solution applied is 10ml.

[0118] Synthetic lamellar body solutions should be used in laparotomies carried out for adhesiolysis in a similar manner to that described for open abdominal surgery. Again in laparascopic abdominal surgery using the technique of pneumo-peritoneum, the peritoneum must be sprayed with a median dose of 1ml at the beginning of the operation and at a median of every 30 minutes throughout the procedure.

[0119] Synthetic lamellar bodies that are sprayed into the peritoneal cavity are removed post-operatively by drainage through the opercula of the lymphatics in both domes of the diaphragm, passing through the thoracic duct into general circulation. Synthetic lamellar bodies

are readily phagocytosed (as are natural lamellar bodies) by the reticulo-endothelial system. The load obtained through use of a total median dose of 10ml in a four hour operation would cause no overloading of the reticulo-endothelial system. In addition to this route of dispersal of synthetic lamellar bodies, there are two other principle modes of uptake in metabolism. As with natural lamellar bodies, synthetic lamellar bodies are phagocytosed by peritoneal macrophages which recycle the phospholipids, as occurs in pulmonary alveoli, for absorption by mesothelium as a substrate to produce new lamellar bodies. Thus, any excess of synthetic lamellar bodies in the post operative period provide a large pool of phospholipid substrate to support high levels of lamellar body production. The maintenance of lamellar body secretion in the early post-operative period serves not only the down regulation of extravascular fibrin formation, but enhances the non-stick role in reducing friction between the layers of the peritoneum.

[0120] Characteristically, the junctional regions between mesothelial cells is sloping. Thus mesothelial cells overlap. Mesothelial cell nuclei show specific nuclear characteristics found in cells subjected to extremes of stretching. Thus, mesothelium in areas which can expand up to 10 times their normal circumference must be subjected to large increases in surface area in order to maintain an intact cellular cover. Lamellar bodies secreted onto the lumenal surface by mesothelium pass between the cells into the junctional regions, where they are located in normal peritoneum. Their regular presence in the sloping, elongated junctional regions serves as an important function in allow frictionless sliding between cell borders to allow stretching without exposing bare areas between cells. Providing an excess of synthetic lamellar bodies in the postoperative period, where the inflamed submesothelial tissue shows varying degrees of oedema and stretching of the overlying mesothelium, serves as an important added protection against the splitting and separation of mesothelial cell layer and continuing the postoperative oozing of fibrinogen and fibrin formation.

Operations in Other Serous Cavities

[0121] Procedures using lamellar bodies in solution are applicable in the prevention of adhesions during surgery carried out in the pericardial and pleural cavities. In the past, there was a disregard of the occurrence of pericardial adhesions to the chest wall, as interference with cardiac movements were not considered detrimental to cardiac function. Also, it was believed that a single open cardiac operation was all that an individual patient would require in his remaining lifespan. However, more recently serial cardiac operations have become increasingly common. This means that the time spent by the surgeon in laborious dissection of adhesions between the heart and anterior chest wall has added considerably to both time and difficulty in clearing the area prior to an operation being carried out. The administration of lamellar body solution on opening the pericardial cavity can be carried out as in abdominal operations, with an initial spraying of 1ml to parietal and visceral pericardium.

[0122] Lamellar body solutions may also be used in lung surgery to maintain a freely mobile pleura. In several disorders and surgical situations, pleural adhesion may be beneficial and lamellar body solutions would therefore not be used. However, a mobile pleura free of adhesions may be important where there are pleural tumour seedlings and access to all of the cavity for intra-pleural chemotherapy must be maintained. In particular, dense fibrin containing tumour seedlings produce densely collagenous adhesions sequestering metastatic deposits inaccessible to anti-tumour agents.

Incorporation of Other Therapeutic Agents in Lamellar Body Solutions

[0123] The present invention also encompasses the option of incorporating other active agents on and within the lamellar bodies to effect and provide targeted therapeutic benefit during surgery. For example, in peritoneal endometriosis, lamellar bodies can be prepared to contain anti-oestrogen compounds which will serve to suppress endometrial epithelium, as well as suppressing focal dense fibrin formation following adhesiolysis.

[0124] Also, lamellar bodies containing chemotherapeutic anti-tumour agents can be used during operations in patients with abdominal carcinomatosis, as peritoneal tumour deposits classically seed onto denuded areas of the peritoneum, becoming enmeshed in fibrin clots and forming dense adhesions containing sanctuary areas of metastatic tumour deposits. This therapeutic strategy is also applicable to pleural and pericardial cavities.

Lamellar Body Solutions Used in Surgery of Synovial Joints and Tendon Sheaths

[0125] Lamellar body solutions can be used in open and arthroscopic surgery to modify fibrin deposition and to promote healing by first intention by suppressing scarification and preventing joint adhesions. Appropriately, reduced volumes of lamellar body solution, depending on the size of the joint space, should be used.

[0126] Lamellar body solutions can be used in operations on tendons to spray visceral surfaces when exposed, as well as spraying the outer aspects of the tendon sheath to prevent the formation of dense fibrin clots.

Use of Lamellar Body Solutions in Neurosurgery

[0127] In peripheral nerve surgery, lamellar body solutions and sprays should be used when surgery is carried out on the perineureum.

[0128] In intra-cranial and intra-spinal surgery, the meninges are also subject to acute inflammatory reaction to surgical interference, as in other body cavities. Where

fibrin exudation may result in scarification with dysfunctional effects, the use of lamellar body solution is an option. Likewise, cerebro-spinal fluid also contains lamellar bodies secreted by the ependyma. Therefore, operations to relieve intra-cisternal blockage may benefit from the use of lamellar body solutions to counteract any procoagulant activities stimulated by surgery, which would otherwise reverse the intended outcome of the surgical procedure.

[0129] In rheumatoid arthritis, acute inflammation is the cyclic pathological process which leads to joint destruction. In acute inflammation there is a massive exudation of fibrinogen from the hyper-permeable vessels of the highly vascular, inflamed synovium. Thus, fibrin is deposited in peri-articular tissues and the joint of space. In rheumatoid arthritis, fibrin can account for up to 34% of the volume of synovial fluid where it is present as so called rice bodies and flakes, while thick stratified layers cover all of the joint surfaces. Fibrin networks are also widely infiltrated throughout the peri-articular tissues. The repeated widespread deposition of fibrin in the granulation tissue and joint spaces results in healing by second intention, leading to fibrous adhesions, scarification and obliteration of joint space. It is worth noting that intra-articular deposition of fibrin is also a feature of other types of acute joint inflammation, as in gout, pseudo-gout and Reiters Disease.

[0130] Intra-articular injections of lamellar body solution can be used in acute joint inflammation to prevent the formation of dense fibrin clots, and to promote fibrin fragmentation and dissolution. This can be carried out in conjunction with administration of anti-inflammatory medication.

Therapeutic Uses Of Lamellar Bodies (synthetic or natural) In Disorders Of The Middle Ear And Eustachian Tube

[0131] The Eustachian tube connects the cavities of the middle ear with the pharynx. Its sole function is the equalisation of air pressure on both sides of the ear drum. If the Eustachian tube is blocked, the air pressure in the middle ear rises, causing increasing diminution of auditory acuity. In 1982 it was discovered that lining cells in the Eustachian tube secreted pulmonary surfactant. To this day it is not widely appreciated by otolaryngologists that this esoteric finding is of crucial importance in the causation of disease in this part of the body. The surfactant property of the lamellar bodies secreted in this duct perhaps has obscured their understanding that the principle role of lamellar body secretion is not that of a surfactant, but of providing non-stick surfaces which are capable of deblocking fibrin exudates and plugs.

[0132] The Eustachian tube guards a vital function in animal survival by protecting the auditory acuity of both predator and prey. In hominids the recent adoption of the upright position has resulted in sub-optimal drainage of the middle ear, since there has been insufficient evolutionary time for modification of a system standard in all quadrupeds of a horizontal skull and constant forward movement. This anatomical deficit, together with the recent crowding together of the species in large groups, has resulted in a situation where otitis media with effusion or "glue ear" is a present-day epidemic affecting up to one third of all children at some time in their early lives (Bull PD. In: Diseases of the ear, nose and throat. Blackwell Science Ltd. Oxford. 1996.pp 57-60). This condition is due to the accumulation of fluid, often viscous, within the middle ear cleft through blockage of the Eustachian tube and resultant poor drainage into the pharynx. This leads to significant conductive deafness causing developmental and educational impairment.

[0133] The pathology of this condition derives from acute inflammation of the Eustachian tube through extension from the pharynx of viral and/or bacterial infection. As at all sites, the acute inflammatory exudate contains a high proportion of extravascular fibrin whose function is to localise the infection and prevent its spread. Again, massive or persistent fibrinous exudate will heal by second intention, causing sub-mucosal fibrosis, lumenal synechia (fine adhesions), narrowing and blockage of the duct. As at other sites, the pathological sequelae derive from the overwhelming of the lamellar bodies' ability to ensure early removal of extravascular fibrin. Thus the use of lamellar body solution at an early and appropriate stage, through administration on a continuous or intermittent basis by direct injection or through gromits which give access to the middle ear and Eustachian tube will modify fibrin in formation while also lysing preformed old fibrinous exudate.

Novel Use Of Lamellar Bodies In The Treatment Of Lung Disorders

Results of Re-appraisal of Fibrin in Lung Pathology

[0134] The findings of our *in vitro* investigations carried out in respect of the present invention of the highly potent biological action of lamellar bodies on the formation and removal of fibrin has occasioned a critical re-appraisal of the validity of established concepts of the aetiopathogenesis of all lung disorders involving an inflammatory response. These findings reveal the existence of a hitherto unrecognised pivotal role of lamellar bodies in the successful resolution of pulmonary diseases which involve acute inflammation and its inevitable deposition of intra-alveolar fibrin. Obversely, any disorder which reduces pulmonary lamellar body secretion, can now be predicted to have serious pathological effects on the resolution of the inflammatory response by virtue of the failure to promote early removal of fibrin, resulting in healing by second intention, granulation tissue and fibrosis. Thus the role of lamellar bodies as surrogate lamellar bodies assumes novel therapeutic potential for the better resolution of most, if not all, lung disorders where intra-alveolar exudation of fibrin occurs.

Crucial Role of Pulmonary Alveolar Architecture in Nature of Inflammatory Response

[0135] Pulmonary alveoli possess microscopically-thin walls, 20 - 40 microns in thickness, which contain the rich capillary network. If an inflammatory-provoking agent succeeds in passing through the proximal respiratory passages, an acute inflammatory reaction will take place in a region with a highly delicate microscopic architecture which subtends the air sacs. Thus, by virtue of the hyper-vascularity of the thin-walled, honeycombed structure of the lung, it is obvious that the effect of the effusion of fibrin in such a site would have immediate and catastrophic effects on pulmonary function. As in other sites, acute inflammation results in vascular congestion of the capillary network in the alveolar walls, leading to margination of granulocytes, increased permeability of the vessel walls and effusion of fibrinogen-rich exudate around and through the pulmonary epithelium into the alveolar space. Fibrin is thus deposited around the walls of the air sacs in a situation where Type II pneumocytes secrete lamellar bodies as pulmonary surfactant.

[0136] Because of the absence of any knowledge in the biological or medical world of the effect of lamellar bodies, as demonstrated by our research with synthetic lamellar bodies on fibrin formation and removal, from this point on, any current explanation of the course of pathological evolution or resolution of the inflammatory response in the lung must be open to question.

[0137] The role of fibrin in the acute inflammatory response, considered in the light of the structural and functional vulnerability of pulmonary alveoli, it therefore can be no coincidence that the lung was first recognised to be the site of lamellar body secretion, and we now show that additional to whatever surfactant properties they provide, lamellar bodies have a profound effect on the formation and removal of extra-vascular fibrin.

Hyaline Membrane Disease

[0138] Surface active phospholipids accumulating in the lungs during late gestation, lower the surface tension of the foetal pulmonary fluid and reduce the resistance to aeration due to capillarity in the finer airways. Thus an adequate amount of pulmonary surfactant secreted as lamellar bodies must be present at birth for the initiation and maintenance of respiration.

[0139] Neonatal surfactant deficiency gives rise to a condition variously known as Respiratory Distress Syndrome or Hyaline Membrane Disease. Its commonest cause is prematurity, where Type II pneumocytes in the immature lung fail to secrete a sufficiency of surfactant to establish normal physiological conditions for maintenance of respiration. The basic biological concept which totally dominates our understanding of the pathophysiology of this syndrome and which is solely responsible for the only therapeutic strategy, is the role of surfactant in establishing adequate gaseous exchange between alveoli and pulmonary capillaries. No other role for the presence of phospholipid bilayers in pulmonary alveoli is recognised. Thus all pharmaceutical efforts are concentrated on providing surfactant in its most complete and natural form to meet all the physical criteria and pulmonary mechanics of gaseous exchange. However, the older name of Hyaline Membrane Disease historically marks the concern by the pathologists who coined this term, over the striking histological findings in the pulmonary alveoli of neonates dying of this condition. The use of the term "membrane" indicates a physical barrier between alveolar air and the underlying blood vessels. "Hyaline membrane" was an imprecise pathological term for eosinophilic acellular material. Modern histochemistry and electron microscopy have shown that in fact, hyaline membrane consists largely of fibrin.

[0140] The applicant's research has shown that not only are lamellar bodies required for establishing the appropriate physical conditions for gaseous exchange, but that lamellar bodies are a key balancing element in modifying the deposition and removal of fibrin. Thus synthetic or natural lamellar bodies will be used and applied to the respiratory passages and alveoli of neonates to obtain dissolution of the hyaline membrane (fibrin) as a key part of a dual therapy, along with surfactants containing spreading factors for establishment of adequate gaseous exchange.

[0141] Current mortality, despite the use of surfactant, is due to the fact that these preparations do not supply a sufficient density of phospholipids as lamellar bodies to lyse and fragment the fibrin membrane which, if unremoved, completely negates any administration of surface active phospholipids with spreading factors.

Use of Lamellar Bodies in Peritoneal Dialysis

[0142] Exudation of fibrin from the peritoneum frequently occurs in peritoneal dialysis in response to a wide variety of stimuli which provoke an inflammatory response. These include bacterial and fungal infections, endotoxin, antiseptics used in exchange procedures, which have entered the dialysate pathway, pharmacological agents added to dialysate eg, antibiotics. As a novel form of treatment to prevent the recognised pathological sequelae which may result in the abandonment of this life-maintaining therapy, intraperitoneal infusion of a solution containing a high concentration of synthetic lamellar bodies can be used to dissolve formed fibrin and modify forming fibrin, to prevent the genesis of peritoneal fibrosis and the formation of intra-abdominal adhesions, omental adhesions to peritoneal catheter, and catheter blockage.

[0143] When a patient is being removed from peritoneal dialysis, solutions of synthetic lamellar bodies should be infused per catheter into the peritoneum after cessation of dialysis. This is to prevent adhesions forming between areas of peritoneal surface which have been denuded of mesothelial cell cover.

[0144] Sclerosing peritonitis, a rare but serious complication of peritoneal dialysis, where global loss of mesothelium leading to loss of intraperitoneal production of lamellar bodies and global fibrin exudation results in widespread adhesions which cannot be relieved by surgical intervention. This usually fatal complication should now be treated by per catheter infusions of solutions of synthetic lamellar bodies into the peritoneum. At the onset of this condition the patient should receive continuous dialysis in which the dialysate contains a titrated amount of synthetic lamellar bodies. If widespread surgical adhesiolysis is to be carried out, exposure to solutions of synthetic lamellar bodies should begin intra-operatively and be continued under regular abdominal ultrasonic monitoring until a mesothelial cell layer regenerates from stem cells to cover the raw, dissected surfaces of visceral and parietal peritoneum, for a period which should range from twelve to twenty days.

Production of synthetic lamellar bodies

[0145] In this document we have discussed using synthetic lamellar bodies and below provides information relating to one method for carrying this out.

In this invention phospholipid multilamellar microbodies are constructed using specific phospholipids in proportions similar to those found in lamellar bodies in normal tissues. The key feature which distinguishes the phospholipid multilamellar microbodies described in the present Application from liposomes is their low content or absence of cholesterol. In biomedical applications liposomes, as synthetic constructs, are primarily designed for compartmental containment and preservation of pharmaceuticals and diverse agents. Thus they are constructed with high levels of cholesterol which confer a membrane stability and low porosity, mimicking mammalian cell membranes. Therefore it follows that the bilayer concentration of cholesterol is the key determinant of the circulatory half-life for liposomes designed as drug carriers. The inhibitory effect of cholesterol on the up-take of liposomes by the lympho-reticular system, as measured in liver and spleen, is well-established (Patell HM et al. 1983). In direct contrast, phospholipid multilamellar microbodies, modelled on the properties of lamellar bodies, are readily taken up by phagocytic cells and as in the case of liposomes with low cholesterol content , are rapidly removed from circulation by lympho-reticular tissue.

[0146] The principle phospholipid constituents of lamellar bodies are phosphatidylcholine (PC), sphingomyelin (SPH), phosphatidylethanolamine (PE), phosphatidylserine (PS), phosphatidylinositol (PI) and lysolecithin (LPC). The phospholipid composition of lamellar bodies shows slight variation according to the cell of origin.

[0147] PC is the principle phospholipid in lamellar bodies, irrespective of site of origin. The percentage PC concentration varies from around 70% in lung lavage to 45% in synovial fluid (Refs) The next phospholipid in ranking concentration is SPH (5-15%). Thereafter, PE, PS, PI, PG and LPC are present in varying, single digit percentage concentrations in lamellar bodies according to site of origin.

[0148] The preferred composition of phospholipids and cholesterol for phospholipid multilamellar microbodies comprises: PC 54%: SPH 19%: PE 8%: PS 4%: PI 3%: cholesterol 10%. These values are median and the following range of compositions have been found in natural lamellar bodies (private research): PC 44-60%, SPH 15-23%, PE 6-10%, PS 2-6%, PI 2-4%, Cholesterol 4-12%. These figures are percentage by weight.

[0149] LPC may also be incorporated into the multilamellar microbodies at 2% by weight which follows the range found in natural lamellar bodies of 0-3%.

[0150] Phospholipid vesicles in the form of liposomes are, of course, well known. However, liposomes are made by those skilled in the art with high cholesterol concentrations to improve their rigidity. Liposomes containing cholesterol at 20% or below would be considered to be cholesterol poor (Love WG et al, 1990). Liposomes incorporating a high ratio (50%) of cholesterol, where it is equimolar with the phospholipids, have a highly stable structure (Kirby et al, 1980, Senior et al, 1982) and so, until this invention, it would not to our knowledge have been obvious to try using low-cholesterol multilamellar microbodies. The cholesterol content of lamellar bodies derived from pulmonary alveoli has been found to contain around 10% cholesterol (Schmitz G, Muller J 1991) (J Lipid Research. 32:1539).

[0151] The presence of sphingomyelin in natural lamellar bodies and in the phospholipid multilamellar microbodies claimed in the present invention is important. Sphingomyelin is not generally used, to our knowledge, in liposomes and serves to give flexibility and softness to lamellar bodies. Conventional liposome technology teaches that rigidity is better for the delivery of chemicals; however, we have found that flexible, low-cholesterol, sphingomyelin containing phospholipid multilamellar microbodies are ideal for delivery of antigen to antigen presenting cells.

[0152] Phospholipid multilamellar microbodies (synthetic lamellar bodies) are prepared by a technique similar to that used to produce hand-shaken multi-lamellar vesicles (New RRC, 1990). The phospholipid mixture, together with cholesterol in the percentages given by weight are dissolved in a chloroform / methanol solvent mixture (2:1 vol/vol). The lipid solution is introduced into a roundbottomed flask and attached to a rotary evaporator. The flask is evacuated and rotated at 60 r.p.m. in a thermostatically controlled waterbath at a temperature of 30°C until a dry lipid film is deposited. Nitrogen is introduced into the flask and the residual solvent is removed before its connection to a lyophilizer where it is subjected to a high vacuum at room temperature for one hour. After release of the vacuum and following flushing with nitrogen, saline containing solutes (selected antigen) for entrapment is added. The lipid is hydrated within

the flask, flushed with nitrogen, attached to the evaporator, and rotated at 60 r.p.m. at room temperature for thirty minutes. The suspension is allowed to stand for two hours at room temperature to complete the swelling process.

[0153] It can therefore be seen that there are many uses for lamellar body solutions in surgical procedures. It should also be noted that the embodiments disclosed above are merely exemplary of the invention, which may be embodied in many different forms. Therefore, details disclosed herein are not to be interpreted as limiting, but merely as a basis for Claims and for teaching one skilled in the art as to the various uses of the present invention in any appropriate manner.

Claims

1. Lamellar bodies comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use in the treatment of a lung disorder involving inflammatory response.

2. A lamellar body solution comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol containing anti-oestrogen compounds for the treatment of peritoneal endometriosis.

3. A lamellar body solution comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol containing chemotherapeutic anti-tumour agents for use in the treatment of metastasis in perintoneal, pleural and pericardial cavities.

4. A lamellar body solution comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use in the treatment of acute joint inflammation.

5. The lamellar body solution of claim 4 in combination with anti-inflammatory medication.

6. Lamellar bodies comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use in the treatment of Otitis Media.

7. A lamellar body solution comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use in the treatment of scarification and prevention of adhesion of the joints.

8. Lamellar bodies comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use the treatment of lung disorders where intra-alveolar extrudation of fibrin occurs.

9. Lamellar bodies comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol in combination with surfactants containing spreading factors for establishment of adequate gaseous exchange for use in treatment of hyaline membrane disease.

10. Lamellar bodies comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use treatments in combination with peritoneal dialysis.

11. Lamellar bodies comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol in combination with peritoneal dialysis for use the treatment of sclerosing peritonitis.

12. A lamellar body solution comprising phosphatidylcholine, sphingomyelin, phosphatidylserine, phosphatidylethanolamine, phosphatidylinositol and cholesterol for use in the treatment of haematomas.

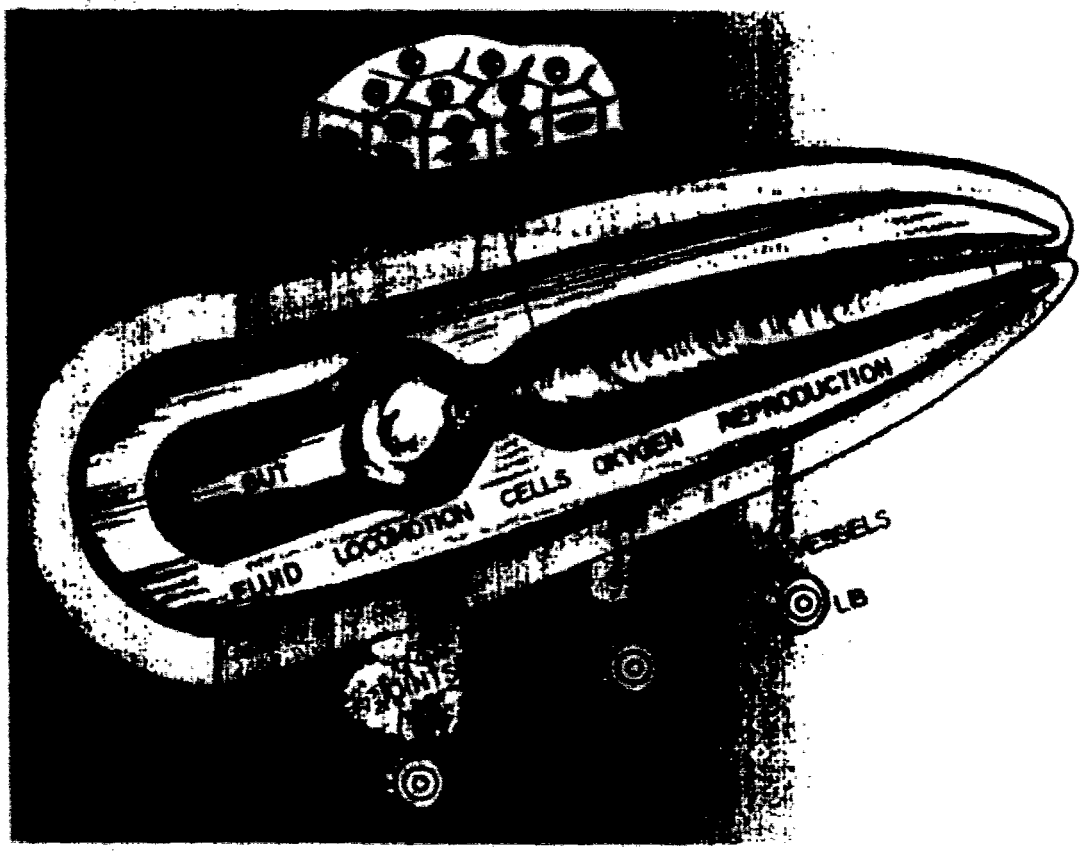

Figure 1

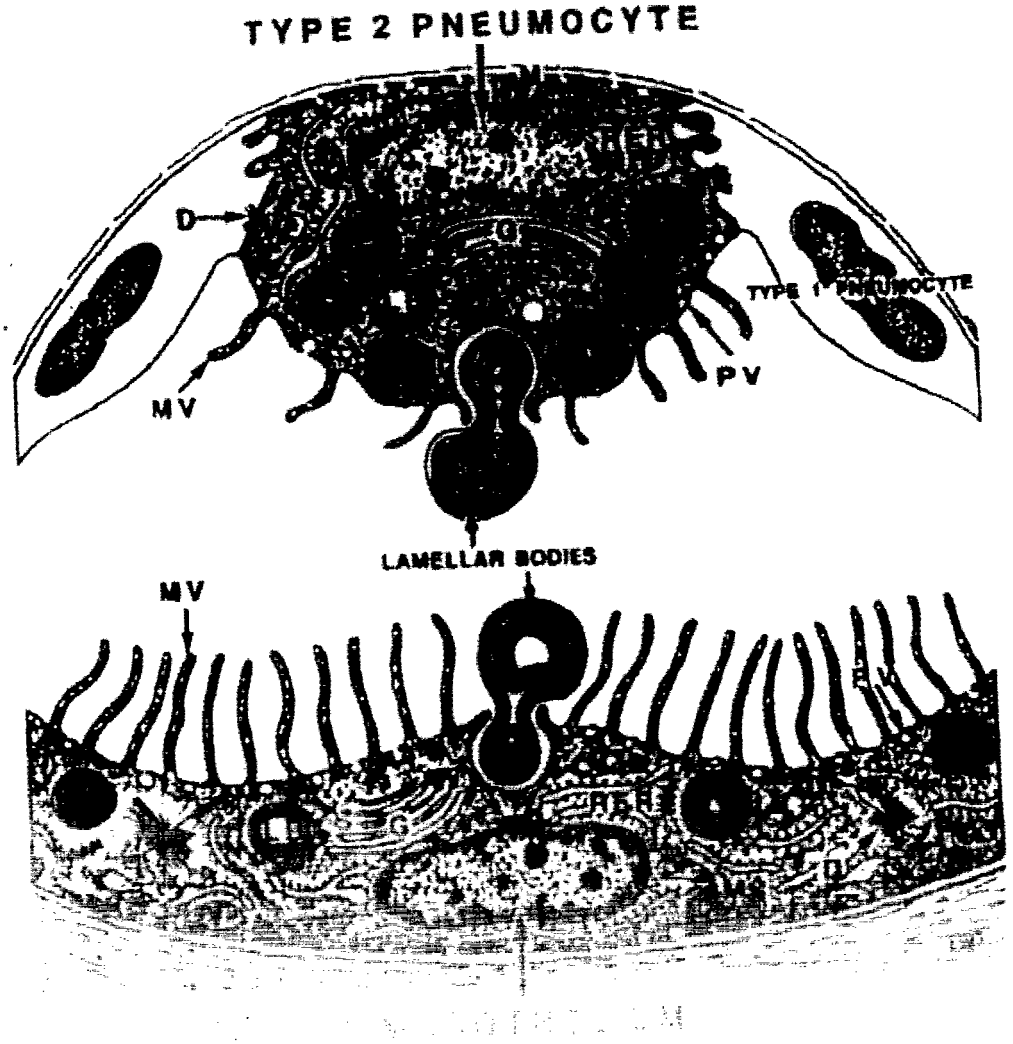

Figure 2

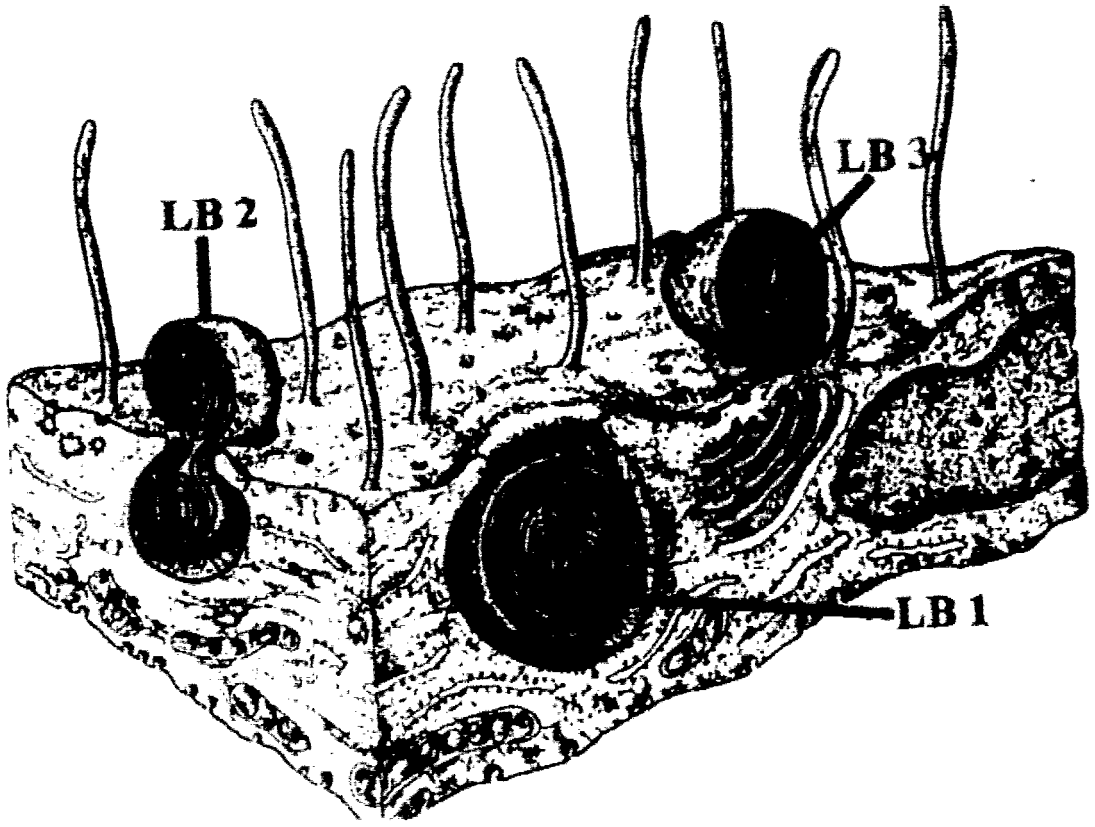

Figure 3

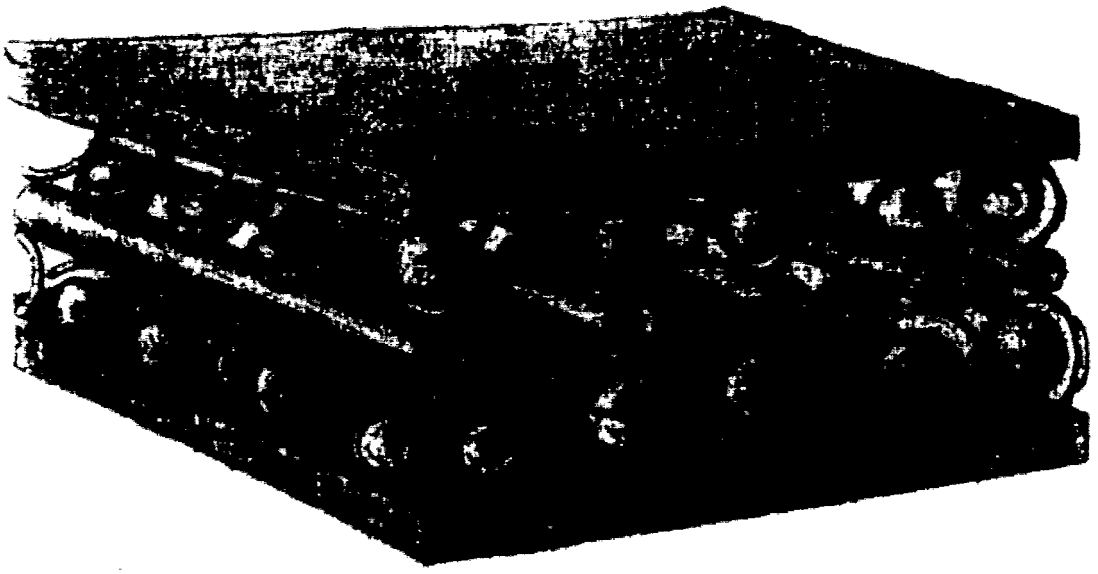

Figure 4

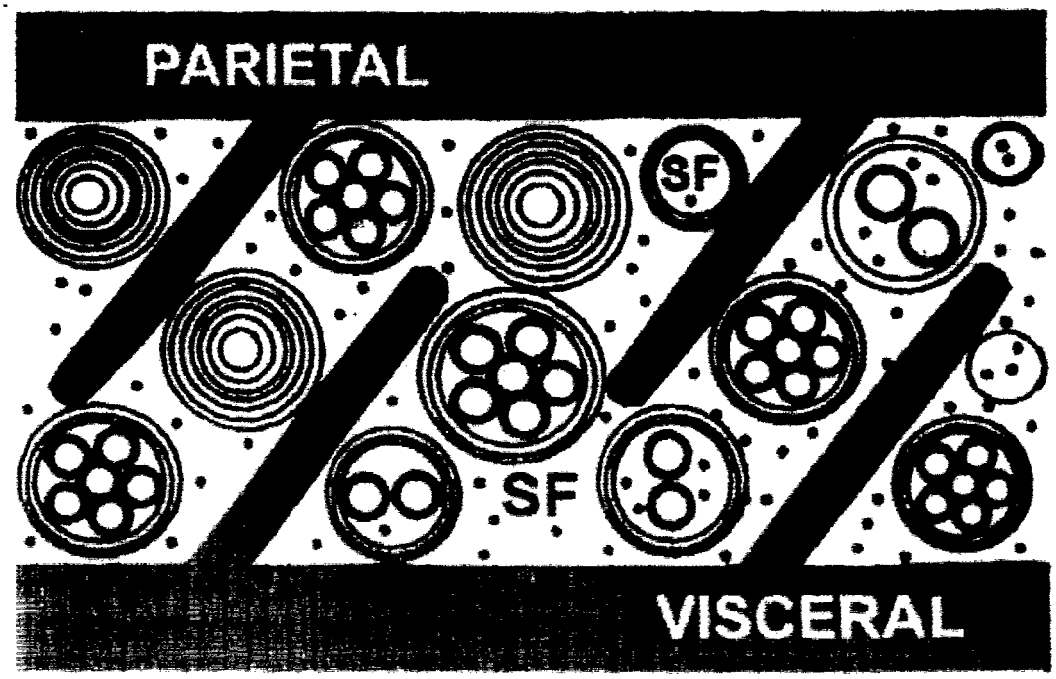

Figure 5

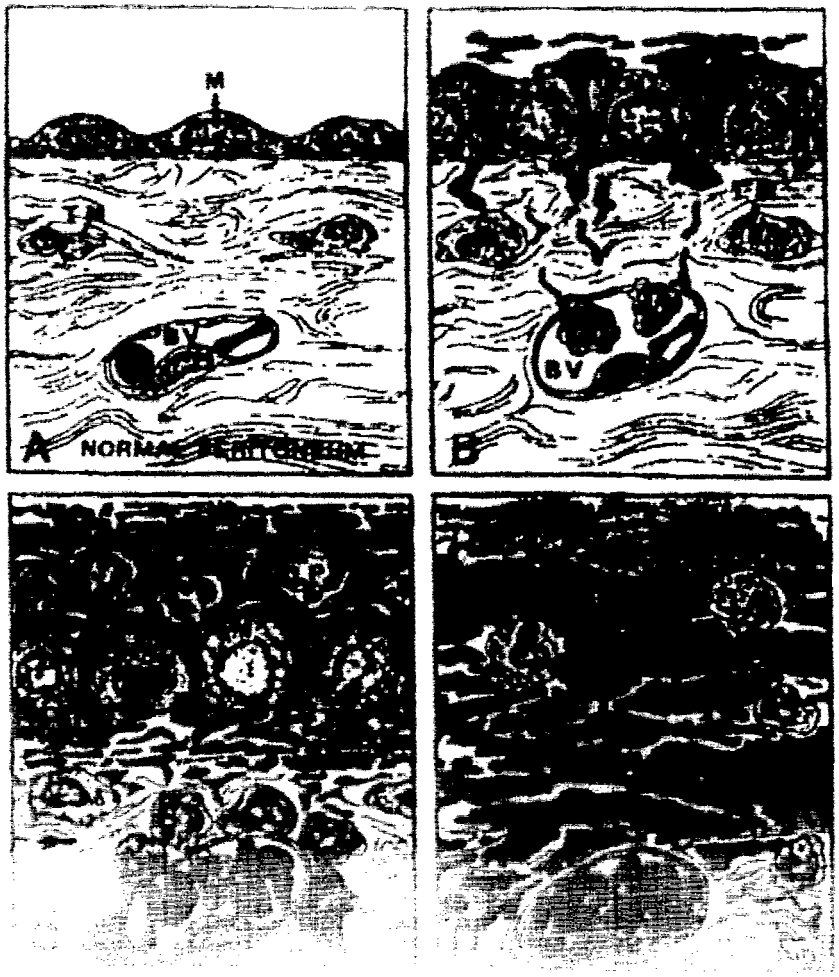

Figure 6

Europäisches Patentamt
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EUROPEAN SEARCH REPORT

Application Number
EP 08 17 0973

DOCUMENTS CONSIDERED TO BE RELEVANT

Category	Citation of document with indication, where appropriate, of relevant passages	Relevant to claim	CLASSIFICATION OF THE APPLICATION (IPC)
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The present search report has been drawn up for all claims

Place of search	Date of completion of the search	Examiner
Munich	3 March 2010	Vermeulen, Stéphane

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EUROPEAN SEARCH REPORT

Application Number
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